

RF Antenna Array at 35 GHz

STATEMENT OF WORK

INTRODUCTION

The NRL Code 5760 IEWS Branch intends to upgrade an existing RF hardware-in-the-loop simulation facility, the CTS, in order to be capable of conducting closed loop simulation with a radar sensor that transmits and receives at a frequency centered at 35 GHz. A portion of this upgraded capability will be provided by NRL, using equipment already purchased. The contractor will be responsible to provide the remainder of the equipment necessary in order to effect the required capability. RF and digital system design and software development expertise are required in order that COTS components will integrate and perform adequately. Close coordination between NRL and the contractor is required since the design of both NRL and contractor portions of the capability need to proceed in parallel and control and signal interfaces will be required between NRL equipment and contractor equipment.

THE CENTRAL TARGET SIMULATOR (CTS)

As a short description of the CTS, imagine a spherical shell with a radius of 75 feet. At the center of this shell is the center of rotation of the sensor antenna. This antenna and its transmitter and receiver unit are mounted on a 3-axis flight table, such that the antenna rotation is also aligned with the flight table's rotational axes. On the inside of the shell are mounted horn antennas so as to form an array that provides a field of view to the sensor of about 20 deg in azimuth by 10 deg in elevation. Extending from just below the center of this shape along the azimuth is an extension of the array, two antennas in elevation, out to an additional 30 deg on either side. A total of 225 antennas currently populate this array, spaced evenly 1.25 deg apart in azimuth and elevation. This array provides the capability to conduct simulation in the frequency range of 8 to 18 GHz.

The array is fed by RF sources, whose signals pass through amplifiers, attenuators, phase shifters and switching trees such that there are two independent channels. The signal paths are arranged to feed signals to the antennas in groups of four, termed a quad. Within a quad (1.25 deg on a side), the power radiated by each antenna is controlled so as to provide an apparent center of radiation anywhere within the quad to an accuracy of 1 milliradian (0.0573 deg). The signals on each channel can appear in any quad simultaneously (even in the same quad). Each channel can be reset for the next signal in under 2 microsec. In this way each channel can represent up to 16 target echo signals during each pulse repetition interval (PRI) of the sensor. At the system level, a scenario is defined to include multiple ships, which may launch chaff and decoys (active or passive) as the simulation engagement is run in the scenario computer. Time from the sensor transmit pulse leading edge is used to delay the return of the echo signal from each target, according to that target's distance downrange in the scenario. The sensor transmit power and each target's radar cross section (RCS) are used to calculate the power of each echo pulse as it is transmitted by the quad. In order to achieve the angular positional accuracy (1 mr) of each target, each component in the system must be calibrated as a function of frequency and power range, likewise the numerous signal paths. The calibration tables that result are used in determination of the signal amplitude for each antenna in a quad for each target, for each PRI.

UPGRADED CAPABILITY - REQUIREMENTS

For the upgraded capability at 35 GHz, we anticipate adding a smaller array to a portion of the spherical shell above one of the existing array azimuthal extensions. This new array would incorporate antennas optimized for transmission at 35 GHz. In addition, the new capability would require switching of target echo signals to the appropriate antennas for the angular position, as well as control of echo pulse timing, pulse duration, and amplitude, in response to target data updated

during the engagement by the scenario computer. For the initial increment of this new capability the contractor-provided portion will include one channel with one-target, angular-position controlled capability. One ship, chaff or decoy in the scenario would be represented using this steerable array.

Additional requirements for the upgraded capability are summarized in Table 1, with comments provided below for further clarification.

- System Communication & Update Rate – the scenario computer updates the engagement geometry and provides target data (range, array azimuth & elevation, RCS or ERP, pulse width, etc.) at a rate of 200 Hz via a fiber optic ring network using VMIC interfaces.
- Independent Feeds, Target Switching and Number of Targets – The feed to be provided by the contractor incorporates the capability to switch the signal to any pair or quad of antennas in the new array. This feed must be capable of switching to the desired antennas with correct amplitude and phase to control fine position, within 1.75 microsecond. This should enable, as an option or future upgrade, up to 8 targets to be represented using this feed during the sensor's PRI.
- Range & Range Accuracy – The feed must be capable of representing a target to as close in range as 2 microseconds after the end of the sensor's transmit pulse, and as far out in range as 250 microseconds. The accuracy of the range position shall be 10 nsec or better. (The range value is updated by the scenario computer each 5 millisec and thus is constant until the next update).
- ERP & Dynamic Range – The effective power radiated by the antennas of the new array shall obtain a maximum value of 50 dBmw; it is highly desirable to increase this capability to 60 dBmw either initially or as a future upgrade. The minimum controlled transmit power shall be -40 dBmw. This results in a dynamic ERP range of 90 dB, or 100 dB if the 60 dBmw maximum is achievable. In addition, it is required to control a target's echo pulse amplitude with a resolution of 0.1 dBmw.
- Antenna Spacing & Angle Accuracy – The anticipated spacing between array antennas is 1.25 deg, using the existing holes in the steel shell that constitutes the mounting surface. This spacing should enable target angular accuracy (between antennas) of 1 milliradian to be achieved (after calibration and with use of the resulting calibration tables) for a sensor with 4 deg beamwidth. The contractor must provide an antenna mounting fixture for each array antenna; the fixture shall enable adjustment of antenna azimuth, elevation, pitch, yaw and roll so that the antenna can be precisely aligned from the sensor's viewpoint so as to be focused on the sensor and with correct polarization.
- Array Coverage – The minimum requirement is to cover 8.75 deg of azimuth, with no elevation adjustment. This is achieved using 8 antennas at 1.25 deg spacing in a linear azimuthal configuration. It is highly desirable, as an option or upgrade, to have a second row of antennas in order to provide 1.25 deg of elevation adjustment, using the antennas grouped in quad addressing.
- Frequency Agility – The sensor has a frequency agile capability, with random pulse-to-pulse frequency steps within +/-500MHz bandwidth. NRL will provide a subsystem that measures the sensor's transmit frequency and outputs both a digital value representing this frequency and an agile local oscillator signal centered at 10 GHz. These outputs are provided in less than 2 microsec from the end of the sensor transmit pulse. Further details will come out of the design process.

- PRI & Pulse Width – The sensor is capable of transmitting several pulse widths between min and max values of 100 nsec to 100 microsec. The time duration between these pulses can also be varied or jittered between min and max values of 300 Hz to 5000 Hz. The array capability must be designed to accommodate these variations. In addition, the array capability must include a continuous wave (CW) mode, which is often used in open loop testing. The target echo pulse may be commanded (via the scenario computer) to be longer than the sensor transmit pulse. This pulse width must have a resolution of 5 nsec.
- Polarization – The sensor is also capable of transmit and receive at either horizontal or vertical polarization. Therefore the array antennas must be capable of being easily switched to either polarization. This is not a real-time requirement and thus the switch can be either manual or under computer control as an initialization setting. Manually rotating each antenna is not an acceptable solution, there must be one switch or one computer command to set the entire array.
- Calibration – Calibration of array components and signal paths is critically important to the capability to generate target echos with correct amplitude and angular position. The contractor must provide the signal ports so that a calibration subsystem can read out signal values that enable the isolation of each component and signal path as the array is commanded to generate a target at any desired location and with any desired amplitude. In addition, the contractor must provide a calibration sensor (to be mounted on the flight table) and a calibration controller with user interface, in order to control the calibration process in a semi-automated regimen. This latter capability would rely on existing NRL equipment to manually position the flight table to any angle required by the ongoing calibration process. A future upgrade would be for the calibration process to directly command the flight table, so that the entire calibration process can be automated.

[MMW Array Requirements Table \(Ctr\) v5.docx](#)

INTERFACES BETWEEN NRL AND CONTRACTOR PORTIONS

- Fiber optic ring network – Numerous computers and controllers are linked via this network. Each uses a VMIC 5565 family (GE-FANUC) interface card to connect to the fiber. For the array upgrade, the scenario computer will update the engagement geometry and provide target data (range, array azimuth & elevation, RCS or ERP, pulse width, etc.) at a rate of 200 Hz. This capability exists and is in use for the present array in CTS. The data protocols and formats will be provided when required.
- Main bang – A trigger signal from the sensor is captured, and propagated (by NRL) wherever required, to define the start of the sensor's transmit pulse. This signal is used to start timing the delay until the transmit of each target echo pulse. That delay depends on the simulated downrange distance from the sensor to the target (as reported and updated via the fiber optic ring) and takes into account the actual propagation within the chamber. The detailed characteristics of the main bang signal will be provided when required.
- FASP outputs – An existing subsystem in the CTS is the Frequency Agile Signal Processor (FASP). This subsystem will be provided, by NRL, with the sensor's transmit pulse as mixed down by 25 GHz (to near center frequency of 10 GHz). The FASP measures the frequency of this signal and within 2 microsecs reports the frequency in a digital word. In addition, it outputs a synthesized RF signal at the frequency commanded by the frequency word. The detailed characteristics of the frequency word and the RF signal will be provided when required.

REFERENCE DOCUMENTS

1. CTS Array Configuration.pdf (CTS 8-18 GHz array antenna layout)
2. CTS Facility Description 2004.pdf (1-page writeup from NRL Major Facilities 2004)
3. CTS Facility Capabilities 2009.pdf (table of CTS specs)
4. Frequency Agile Calibration System Overview 2004.pdf (R. Surratt paper on FACS)
5. CTS Block Diagram v3.vsd (B. McGhee diagram includes CTG, FASP, VMIC)
6. Feed Capabilities.vsd (D. Fischer diagram of MMW Two Target Generation, the NRL portion of the array upgrade [there are 4 other pages in the file, which I think should be withheld])